October 2015

West Sacramento Project
General Reevaluation Report

US Army Corps
of Engineers ®
Sacramento District

WSAFCA
West Sacramento Area Flood Control Agency

APPENDIX A

PLAN

F0RMULATION

Cover Photo: Sacramento River, West Sacramento, and Yolo Bypass, March 2011

Photo courtesy of Chris Austin.

WEST SACRAMENTO PROJECT, CALIFORNIA
GENERAL REEVALUATION REPORT

Appendix A

Plan Formulation

U.S. Army Corps of Engineers
Sacramento District

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American River Common Features

and West Sacramento General Reevaluation Reports Bridging Document

1.0 BACKGROUND

Document Purpose

The purpose of this document is to demonstrate that formulation and identification of the National Economic Development (NED) plans for the American River Common Features (ARCF) and West Sacramento (WS) projects is not affected by investigating the two areas separately. The U.S. Army Corps of Engineers (USACE) is completing General Reevaluation Reports (GRRs) for the ARCF and WS projects. This bridging document accompanies each GRR to explain how the two projects function both independently and together by summarizing the following:

- Existing flood risk management system in the greater Sacramento area
- Flood history of the greater Sacramento urban area
- Future without project conditions for the study area
- Potential system-wide flood risk management alternatives considered
- NED Plan for the ARCF GRR
- NED Plan for the WS GRR
- Effects of Re-evaluating ARCF and WS Projects Separately
- Conclusions

Existing Flood Risk Management System in the Greater Sacramento Area

The city of Sacramento sits along the east bank of the Sacramento River at the confluence with the American River. Immediately across the Sacramento River lies the city of West Sacramento. The cities of Sacramento and West Sacramento are collectively referred to as the greater Sacramento urban area.

Sacramento sits within three distinct basins each protected by a system of levees. The American River South (ARS) basin is protected by 25 miles of levee including the south levee of the American River and the east levee of the Sacramento River. The American River North (ARN) basin is protected by 25 miles of levee including the north levee of the American River, the east levee of the Natomas East Main Drainage Canal (NEMDC), the north and south levee of Arcade Creek, the north and south levee of Dry/Robla Creeks, and the west levee of the Magpie Creek Diversion Channel. The Natomas (NAT) basin is not included in the ARCF GRR.

West Sacramento sits within one distinct basin protected by a system of levees. This basin is split in two by a navigation project. This basin is protected by 50 miles of levee including the west levee of the Sacramento River, the south levee of the Sacramento Bypass, the east levee of the Yolo Bypass, and a canal embankment levee on the south. Refer to Plate 1 for a map of the greater Sacramento urban area.

The Sacramento River comes from the far north portion of California and passes between the cities of Sacramento and West Sacramento. Upstream of the greater Sacramento urban area, major tributaries to the Sacramento River includes the Feather River, the Colusa Basin Drain, and Butte Creek. Within the urban study area, the major tributary is the American River. Up until the flood of 1909, engineers attempted to keep all flow within the Sacramento River. The 1909 flood, along with other floods previously, caused levee failures. After the 1909 flood, the State of California and the Federal government decided to build a bypass system. Over the next 20 years, the bypass system was constructed.

The Sacramento River's bypass system starts approximately 100 miles above the Natomas basin where flow spills out of the Sacramento River to the east upstream of the project levees and into the Butte Basin. Flow in the Butte Basin feeds into the Sutter Bypass. The Sutter Bypass then flows into and across the Sacramento River and is then called the Yolo Bypass. The Fremont Weir sits at the very upper limit of the Yolo Bypass and controls when flow starts to spill into the Yolo Bypass. Continuing downstream, the Yolo Bypass passes just to the west of the city of West Sacramento.

Further down the Sacramento River in the city of Sacramento, the American River comes into the Sacramento River from the east. The Sacramento Weir and Bypass is located approximately three miles upstream of the American River. The primary purpose of the Sacramento Weir and Bypass is to take high flows from the American River over to the Yolo Bypass.

Below the greater Sacramento urban area, the Yolo Bypass and the Sacramento River come back together near the town of Rio Vista. Combined flow then continues out to San Francisco Bay and the Pacific Ocean. Refer to Plate 2 for a map of the Sacramento River Flood Control System.

History of Flooding in the Greater Sacramento Area

The city of Sacramento last flooded in 1909. Folsom Dam and the north levee of the American River, as well as the rest of the Sacramento River Flood Control Project, were all completed by the mid-1950s. 1955 marked a flood of record in the Sacramento Valley. 1964 was also a somewhat significant flood event on the American River. 1986 was a significant flood event that replaced the flood of record. And 1997 was a flood event that was almost as significant as the 1986 event. The 1955, 1964, 1986, and 1997 flood events caused much distress to the levees protecting the greater Sacramento urban area. The main causes of distress included seepage, stability, and erosion. Figure 1 below shows seepage and stability distress on the Sacramento River during the 1986 event that required flood fighting to prevent a full levee breach. Figure 2 below shows erosion distress on the American River that occurred during the 1986 event but was not known about until after flow receded.

For the 1986 flood event, potential levee overtopping became a significant threat on the American River because of Folsom Dam releases having to be ramped up above the objective release of 115,000 cfs and up to 134,000 cfs, which caused flow to be within one foot of the top of levee in certain locations along the American River. Some of these deficiencies have been addressed by seepage and stability improvements authorized in WRDA 1996, WRDA 1999, EWDAA 2004, and WRRDA 2014 for the city of Sacramento as part of the ARCF project, seepage and stability improvements authorized in WRDA 1992 for the city of West Sacramento as part of the WS project, and storage and release improvements for Folsom Dam authorized in WRDA 1999 and EWDAA 2004. Many deficiencies remain which are the subject of the ARCF and WS GRRs.

Figure 1. Seepage and stability distress in Natomas during the 1986 flood event

Figure 2. Erosion distress on the American River after the 1986 flood event

<u>2.0</u> FUTURE WITHOUT PROJECT CONDITIONS2.1 Legacy of Historic Levee Construction Techniques

The Sacramento River Flood Control Project, including the portion within the greater Sacramento urban area, was constructed using either a clamshell dredge or a suction dredge retrieving material from the adjacent river and piling it up along the levee alignment. Figures 3 and 4 show typical levee construction by both clamshell dredge and suction dredge methodology.

Figure 3. Typical clamshell dredge levee construction on the Sacramento River system

Figure 4. Typical suction dredge levee construction on the Sacramento River system

The material dredged from the adjacent river was predominately sand with very little silt that tends to be non-cohesive. Additionally, the land on which the levees were constructed tended to be materials similar to the material dredged from the adjacent river. These materials are very poor for levee safety. Water is able to freely move through and under the levee causing severe seepage problems. Water seeping through the levee tends to carry levee material with it, weakening the levee.

Additionally, in much of the study area, the levees have narrower crown widths and steeper side slopes than current engineering standards. In some locations, the waterside slope is steeper than 2 to 1 and the landside slope approaches 1 to 1, which coupled with the nature of the levee fill material, causes a significant stability issue as well.

In addition to the inherent seepage and stability issues of the levees and levee foundations, the potential for an erosion induced levee failure is significant. In many cases, the levees were built somewhat set back from the main channel of the adjacent river. Over the course of about a hundred years, much of the waterside berm left during initial construction has eroded away. This occurred because flow was confined between the levees to much higher stages and velocities than would have occurred prior to the levee construction. In some locations, 100 feet of berm has eroded away making it necessary to armor the waterside levee slope to stop additional erosion into the levee foundation and undermining of the levee. The Sacramento River Bank Protection Project constructs rock riprap bank protection at damaged sites. The problem with this approach is it reacts to erosion after it happens. Erosion has led to partial levee failures at very frequent events.

2.2 Legacy of Historic Levee System Configuration

Reclamation of the Sacramento Valley began around 1850. Up until the flood of 1909, all reclamation activities focused on forcing all flow to be confined to the main rivers. This was a trial and error period with frequent levee failures, including failures in the 1909 event. After this event, the State of California and the Federal Government decided on the need for the bypass system. The State approved the bypass system and the overall Sacramento River Flood Control Project in 1911 and the Federal Government authorized it in 1917. The bypass system and overflow weirs were then constructed over the next 15 years.

The flood of 1909 and a flood that occurred in 1907 were the only significant flood events for which detailed streamflow gage data is available.   Initial design of the State and Federally authorized flood control system was developed around the floods of 1907 and 1909. In 1927, a new flood of record occurred for a portion of the Sacramento River system. The larger magnitude flow on these reaches was incorporated into the overall design of the entire flood control system. The entire Sacramento River Flood Control Project was completed in the mid 1950s.

In 1955, a new flood of record occurred for the entire Sacramento River system. This flood event caused a levee failure that inundated Yuba City, as well as a few other levee failures into relatively rural areas. Another flood event occurred in 1964 that was more substantial than every other event that occurred prior to the 1955 event. In 1986, again a new flood of record occurred for the entire Sacramento River system. This flood event caused a levee failure that flooded smaller communities around the City of Marysville, as well as a few other levee failures into relatively rural areas. In 1997, a flood event occurred that was nearly as significant as the 1986 event. This flood event caused a levee failure that nearly flooded the small community of Meridian, as well as a few other levee failures into relatively rural areas.

With the increasing size and frequency of storms since the mid 1950s, the levee system has been stressed by conveying more flow than it was intended to convey. This has partially been mitigated by the construction of various reservoirs around the Sacramento Valley. However, there are numerous unregulated tributaries that contribute flow to the Sacramento River system. Therefore, the effect the reservoirs have on attenuation of flow in the Sacramento River system is minimal.

2.3 Prior Decisions on Folsom Dam

The 1986 flood event nearly caused the inundation of the cities of Sacramento and West Sacramento. After this event, the Corps was directed to complete a feasibility study to identify Federal interest in flood risk reduction measures. For American River, studies were completed in 1991 and 1996, with each identifying a new dam to be constructed on the north fork of the American River near the town of Auburn, plus levee improvements in the greater Sacramento area, as the NED plan. For various reasons, Congress chose not to authorize Auburn Dam and instead authorized modifications to Folsom Dam.

The Folsom Dam Modifications and Raise Projects are intended to control a 200-year flood event with a peak release of 160,000 cfs. The current objective release from Folsom Dam is 115,000 cfs. The original intent was to modify the existing Folsom Dam to be able to accomplish this higher objective release, however, due to technical complexities, it was decided to build an auxiliary spillway and control structure to accomplish this. This project is also combined with a USBR dam safety project and is therefore referred to as the Folsom Dam Joint Federal Project (JFP).

Prior authorizations in WRDA 1996, WRDA 1999, and EWDAA 2004 for the ARCF project were intended to improve the conveyance capacity of the levee system in the greater Sacramento area to safely convey the new release of 160,000 cfs. The 1997 flood event along with subsequent investigation combined with Hurricane Katrina, the inundation of New Orleans, and subsequent investigation have all illustrated that much more work needs to occur to the levee system protecting the greater Sacramento urban area.

2.4 General Problem Identification for the Greater Sacramento Urban Area

There are four main problems with the levee system for the greater Sacramento urban area: seepage, stability, erosion, and height. In general, three of these problems are a result of levee construction techniques (seepage, stability, and erosion). The other problem (height) is a result of the design conveyance capacity of the overall Sacramento River system based primarily on the 1907, 1909, and 1927 flood events.

<u>Levee Construction Technique Problems</u>

<u>Seepage:</u> Water traveling through and/or under a levee carries soil particles with it, greatly weakening the entire structure. If this condition is not corrected, it will likely lead to a levee failure. Even with flood fighting efforts, this condition occasionally leads to a levee failure. Figure 5 below shows a general seepage condition on the Sacramento River system.

<u>Stability:</u> Because the levees are built out of relatively non-cohesive materials (sand), and are in general built to a poor geometry, stability problems cause much distress in flood conditions. Like seepage, if this condition is not corrected, it will likely lead to a levee failure. Figure 6 below shows sloughing of a levee as a result of stability problems.

Figure 5. General seepage condition on the Sacramento River system

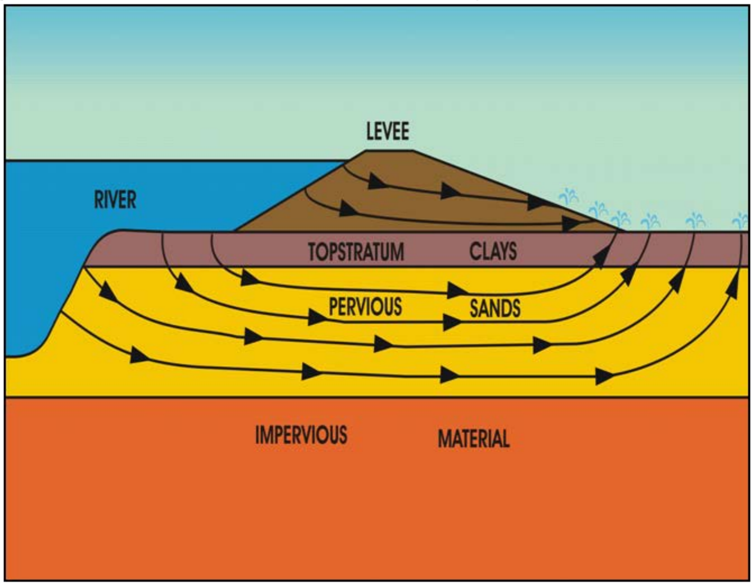


Figure 6. Sloughing of levee slope as a result of stability problem

Erosion: Because the levees are built out of relatively non-cohesive materials (sand), and are subjected to very severe (12 feet per second) river currents in some cases, erosion of the berm and levee slope is an ongoing concern. When erosion is occurring during a flood event, it is not evident and does not become evident until a full levee failure is in progress. Figure 7 below shows erosion on the Sacramento River at a site in the city of Sacramento.

Levee System Configuration Problem

The Sacramento River and Yolo Bypass combined were designed to convey 469,000 cfs, based primarily on the floods of 1907, 1909, and 1927. In 1986, that flow was exceeded by over 100,000 cfs. The American River was designed to convey 115,000 cfs. This amount was based on the hydrology used to design Folsom Dam and the north levee of the American River in the late 1940s. In 1986, there was nearly 20,000 cfs more than that amount in the American River. The 1986 flood event was approximately an 80-year event.

The 1986 and 1997 flood events each stressed the levee system for the greater Sacramento urban area beyond what it was intended to convey. With the urbanization of the greater Sacramento urban area, the design conveyance capacity past the cities is insufficient to minimize the risk of catastrophic flood damages.

Figure 7. Erosion of the levee slope on the Sacramento River.

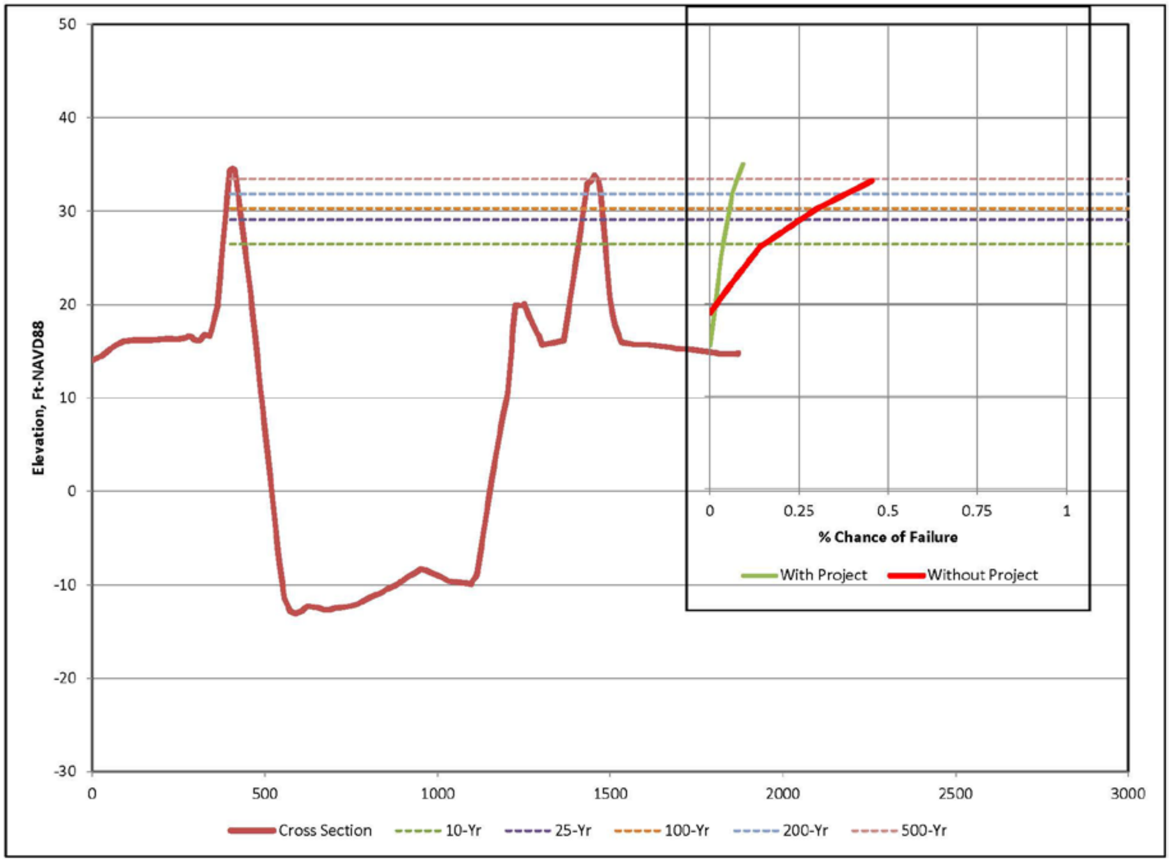
2.5 General Probability of Levee Failures into the Cities of Sacramento and West Sacramento

The GRRs for both ARCF and WS have been developed using consistent methodology and tools. For hydrology, both studies are using the updated Sacramento/San Joaquin Rivers Comprehensive Study hydrology. For hydraulics, both studies are using a HEC-RAS model of the entire Sacramento River Flood Control Project. For geotechnical, both studies are using accepted seepage and stability model software with inputs based on site specific geotechnical explorations. For risk analysis and economics, both studies are using the HEC-FDA software. For cultural resources, environmental, real estate, and civil design, methodologies are the same between the two studies.

The analysis for both studies has calculated water surface elevations for various frequency events along all levees adjacent to the greater Sacramento urban area. The analysis for both studies has also developed levee performance curves for typical reaches within each city.

Figure 8 below shows a cross section of the Sacramento River in the Pocket Area of Sacramento, along with the levee performance curve for that location. In the cross section, Sacramento is to the left side of the left levee and channel and West Sacramento is to the right side of the right levee and channel. Also shown on the cross section is the calculated water surface elevation for a 10-, 25-, 100-, 200-, and 500-year event. Elevations on the levee performance curve are at the same level as the cross section so that the water surface elevations in the channel can be compared to the levee performance curve.

Figure 8. Cross Section of the Sacramento River in the Pocket Area Along With the Levee Performance Curve for that Location



Based on this graphic, it can be seen that the 10-year water surface elevation has approximately a 15% chance of causing a levee failure into Sacramento. For the 25-, 100-, 200-, and 500-year events, the chances of have a levee failure into the city is 25%, 30%, 40%, and 45% respectively.

The without project condition levee performance curve is a composite curve that includes a component for through and under seepage, stability, and judgment. At this particular location, through seepage is not a concern because a shallow seepage cutoff wall was constructed there in the early 1990s. Additionally, stability in general is not a concern because of the presence of this same wall. Therefore, the drivers for the levee performance curve at this particular location are underseepage and judgment. Between the two, approximately 60% of the risk is driven by judgment and 40% is driven by underseepage. Judgment is a composite curve representing risk from vegetation, encroachments, rodent activity, access, and erosion. The risk from each of these components is significant but the single largest driver of the judgment curve is erosion.

The levee performance curve shown above is for the Sacramento side of the Sacramento River. The levee performance curve for the West Sacramento side of the river is very similar. Therefore, relative risk of levee failure is similar for West Sacramento as it is for Sacramento.

3.0 SYSTEM-WIDE IMPROVEMENT ALTERNATIVES

System-wide flood risk management alternatives for the Sacramento River were evaluated to determine if they would provide a cost-efficient solution without levee improvements for individual basins in the greater Sacramento urban area. Following is a brief description of each of the system-wide alternatives considered, the flood risk reduction effects of each alternative, and the reason each alternative was excluded from further consideration.

American River Upstream Storage

Studies completed in 1991 and 1996 identified Auburn Dam as the NED Plan to address flooding on the American River. Auburn Dam would be able to control a much larger flood event than Folsom Dam alone and would provide a higher level of flood risk reduction to the greater Sacramento urban area.

For Auburn Dam to be effective, the combined objective release from Auburn and Folsom Dams would need to be maintained at 115,000 cfs to leave storage available for the flood peak in each reservoir. With an objective release of 115,000 cfs, almost all of the levee improvements included in the NED Plans for both the ARCF and WS GRRs would still be necessary because the existing levee system is unreliable even at relatively low flow stages above the levee toe.

Specific levee improvements that would be required in conjunction with Auburn Dam include all seepage and stability improvements, all of the levee raising, probably the Sacramento Weir and Bypass widening, and almost all of the erosion protection improvements included in the ARCF and WS TSPs. Additionally, levee raising along the Sacramento River and Yolo Bypass would be required to protect against upstream Sacramento River driven floods of similar magnitude as Auburn Dam would be designed to control (approximately 400-year level of performance as identified in the 1996 report). This levee raising, possibly coupled with widening the Sacramento Weir and Bypass would be beyond the level needed for the two NED Plans because it would need to convey a 400-year flood event from the Sacramento River as opposed to an approximately 200-year event, which is the level of the NED Plans.

This alternative was excluded from further consideration in the GRRs because it would require almost all (if not all) of the features of both NED Plans. The levee improvements in the greater Sacramento urban area and the conveyance improvements of widening the Sacramento Weir and Bypass are required components of a comprehensive flood risk reduction alternative involving upstream storage on the American River and are therefore “no regrets” features. The currently proposed levee and conveyance improvements would be necessary and would provide benefits whether or not additional upstream storage is constructed in the American River watershed.

Transitory Storage In Rural Basins Upstream of the Greater Sacramento Urban Area

A possible way to improve flood risk for the greater Sacramento urban area is to temporarily store flood volume in some of the rural area adjacent to the Sacramento River, the Feather River, the Yolo Bypass, and/or the Sutter Bypass.

This temporary or transitory storage has the effect of reducing water surface elevations at the northwest corner of Natomas for various frequency events by between 2 and 3 feet. Further down the Sacramento River and Yolo Bypass, this decrease in stage reduces to zero, essentially giving no benefit to most of the greater Sacramento urban area. There are two primary reasons why this is the case. First, there is a tremendous volume of water coming down the Sacramento Valley towards the greater Sacramento urban area and when a basin is used for temporary storage, the volume of water taken out of conveyance in the river channels and put into storage is relatively small and insignificant. Second, the contribution of the Folsom Dam flood releases being conveyed down the American River eliminates any small decrease in stages that might have been experienced by transitory storage.

Therefore, with transitory storage, all of the levee improvements included in both NED Plans for ARCF and WS are still necessary, with transitory storage not providing nearly enough economic benefit to justify the very large cost. Therefore, transitory storage was excluded from further consideration.

Yolo Bypass Widening and Conveyance Capacity Improvements

Another possible way to reduce flood risk for the greater Sacramento urban area is to improve the amount of conveyance and the reliability of conveyance of the Yolo Bypass. This alternative would likely include widening the Yolo Bypass by setting back the east levee from Fremont Weir down to the Sacramento Bypass, widening the Fremont Weir, removal of embankment within the bypass at the Yolo Shortline Railroad, the Union Pacific Railroad, and Interstate Highway 80, construction of a diversion structure from the Yolo Bypass into the Sacramento River Deep Water Ship Channel (DWSC), construction of a closure structure on the DWSC, and construction of seepage and stability improvements of all of the existing levees along the bypass.

Yolo Bypass conveyance improvements have the effect of reducing water surface elevations at the northwest corner of Natomas for various frequency events by up to 3 feet. Further down the Sacramento River and Yolo Bypass, this decrease in stage reduces to nearly zero, essentially giving no benefit to most of the greater Sacramento urban area. The primary reasons why there is not more of a stage reduction is the same as for the transitory storage alternative.

Therefore, with Yolo Bypass conveyance improvements, all of the levee improvements included in both TSPs for ARCF and WS are still necessary, with Yolo Bypass conveyance improvements not nearly providing enough economic benefit to justify the very large cost. Therefore, for purposes of these two studies, it was screened out. It is important to note that the Yolo Bypass widening does potentially provide benefits elsewhere and is being looked at by the State of California as part of the Central Valley Flood Protection Plan (CVFPP), and this feature is still being analyzed by others but would not affect (strand)levee improvement in the greater Sacramento urban area.

Reoperation of Upstream Reservoirs

Another possible way to reduce flood risk for the greater Sacramento urban area is to reoperate upstream reservoirs to provide more flood flow attenuation within existing reservoirs. There are three main reservoirs upstream of Folsom Dam that are intended for hydropower, including Union Valley, French Meadows, and Hell Hole, that could be reoperated for flood flow attenuation. Surrounding the Sacramento Valley to the north of the greater Sacramento urban area, Shasta, Oroville, Bullards Bar, Englebright, and Black Butte are all reservoirs that have some flood flow attenuation but also have a water supply and hydropower component; some of the water supply and hydropower storage space could be converted to flood flow attenuation at these reservoirs as well.

On the American River, the three hydropower reservoirs are relatively small compared to Folsom Dam. Therefore, unless significant storage space was to be converted to flood control, very little benefit is provided by reoperation of these reservoirs.

On the Sacramento River to the north, as pointed out in a previous section, there are many tributaries to the Sacramento Valley that are unregulated. Therefore the effect of reoperation of the existing reservoirs is quickly made irrelevant as the non-regulated streams and rivers contribute flow to the Sacramento Valley.

Therefore, with reoperation of upstream reservoirs, all of the levee improvements included in both NED Plans for ARCF and WS are still necessary, with reoperation of these reservoirs not providing nearly enough economic benefit to justify the very large cost. Therefore, the reoperation of upstream reservoirs was excluded from further consideration.

Overall Conclusions of System-Wide Improvement Alternatives

Every system-wide improvement alternative has minimal to no impact on stage reduction in the greater Sacramento urban area and requires almost all (if not all) of the levee improvements included in each of the NED Plans in order to significantly reduce the flood risk for the greater Sacramento urban area. Consequently, levee improvements in the greater Sacramento urban area are a first increment to any system-wide improvement plan. The State of California is formulating the "Central Valley Flood Protection Plan" (CVFPP) which is considering some or all of these system-wide plans. For purposes of their plan formulation efforts, they consider the levee improvements in these two GRRs to be "early implementation projects" and necessary integral increments to the overall CVFPP.

In Figure 8 above, if the water surface elevations were dropped by a half of foot on the stage reduction (which is an upper limit at this location as a result of the system-wide alternatives considered), very little risk reduction is provided to the greater Sacramento urban area. Therefore, the conclusions from evaluation of the system-wide alternatives are: 1) There is not a system-wide alternative that alone significantly reduces the flood risk to the greater Sacramento urban area; 2) Any system-wide plan still requires levees to be improved so that they can more reliably convey even moderate flows; and 3) Almost all of the levee improvements proposed in the ARCF and WS GRRs are integral to any system-wide plan that may be implemented in the future.

4.0 AMERICAN RIVER COMMON FEATURES NED PLAN AND LPP PLAN

After the system-wide plans were determined to alone not significantly reduce flood risk for the Sacramento urban area, levee improvements within the urban area were determined to be required for significant flood risk reduction. The NED Plan and a Locally Preferred Plan (LPP) were identified with the most substantial difference between the two being inclusion of a widened Sacramento Weir and Bypass in the LPP but not the NED Plan. Following are details of the NED Plan for the ARCF GRR, identified by basin.

American River South (ARS) Basin

- Sacramento River: Approximately 9 miles of seepage cutoff walls, 2.5 miles of geotextile stabilized slope, 2 miles of slope flattening, 10 miles of rock riprap protection, and 9 miles of levee raising will be constructed.
- American River: Approximately 7 miles of rock riprap protection will be constructed.

American River North (ARN) Basin

- American River: Approximately 4 miles of rock riprap protection will be constructed.
- Natomas East Main Drainage Canal (NEMDC): Approximately 1 mile of seepage cutoff walls will be constructed.
- Arcade Creek: Approximately 4 miles of seepage cutoff walls, 4 miles of geotextile stabilized slope, and 4 miles of existing floodwall will be raised.
- Magpie Creek Diversion Channel: Approximately 0.5 miles of the Magpie Creek Diversion Channel west levee will be raised and the levee will be extended approximately 1,000 feet upstream.

For the NED plan, specific locations for the seepage, stability, erosion, and overtopping improvements for both basins are shown on Figure 9 below. Figure 8 above shows the with-project levee performance curve, and by comparing to the without project condition curve, the relative risk reduction provided by the plan features can be seen.

Following are details of the LPP for the ARCF GRR, identified by basin.

- Sacramento River: Construction of about 9 miles of slurry cutoff walls and about 10 miles of rock bank protection along the Sacramento River east levee, as well as about 2.5 miles of geotextile stabilized slope, 2 miles of slope flattening, and less than 1 mile of levee raise.
- Eastside Tributaries: Construction of about 4 miles of slurry cutoff walls and 4 miles of levee raises along the NEMDC and Arcade Creek levees.
- American River: Construction of rock bank protection and launchable rock trenches along 4 miles of the north bank and 7 miles of the south bank of the American River.
- Sacramento Bypass: Widen the Sacramento Weir and Bypass by 1,500 feet.

For the LPP, specific locations for the seepage, stability, erosion and overtopping improvements for both basins along with the widening of the Sacramento Weir and Bypass are shown on Figure 10 below.

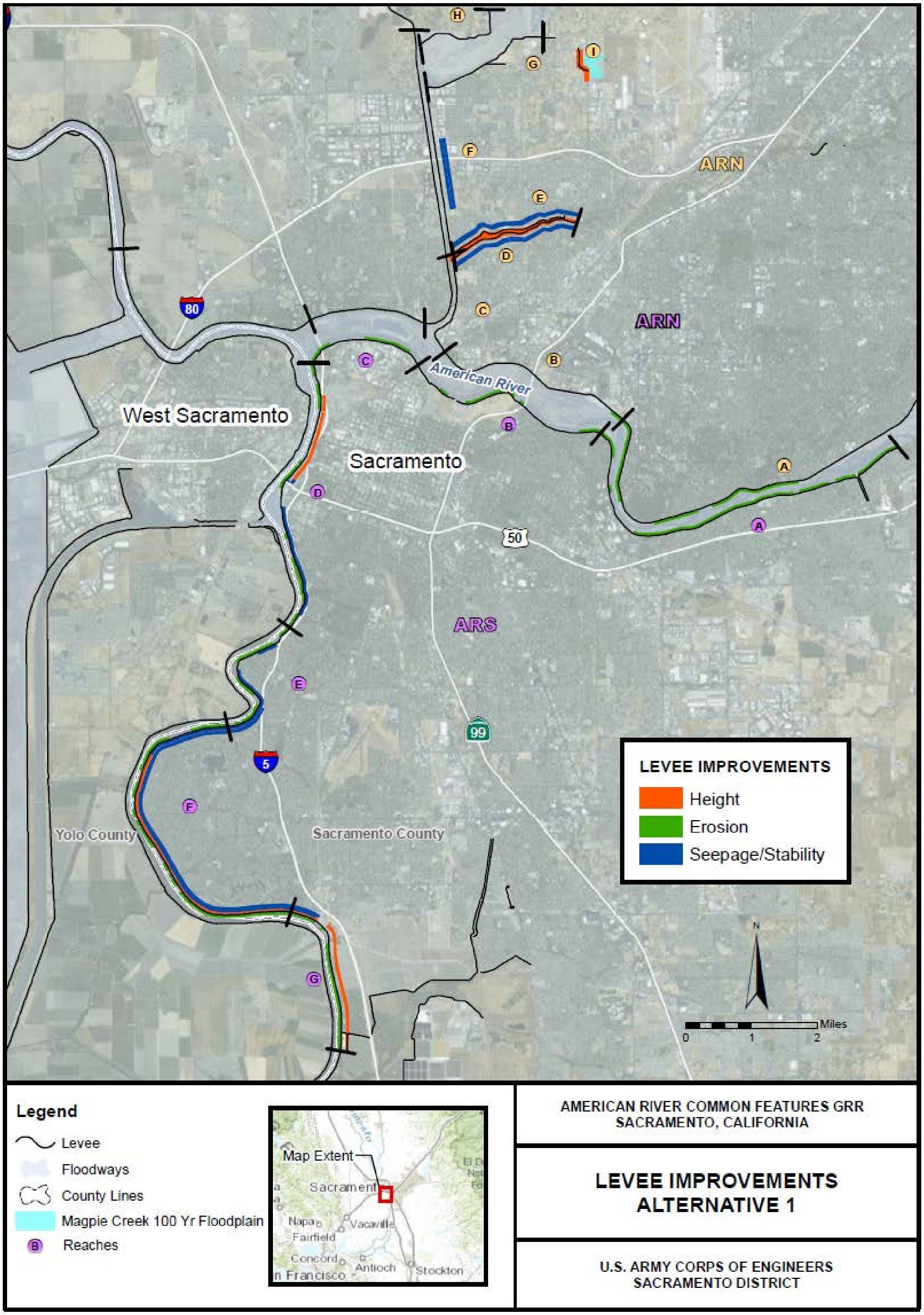


Figure 9. NED Plan Features for the American River Common Features GRR

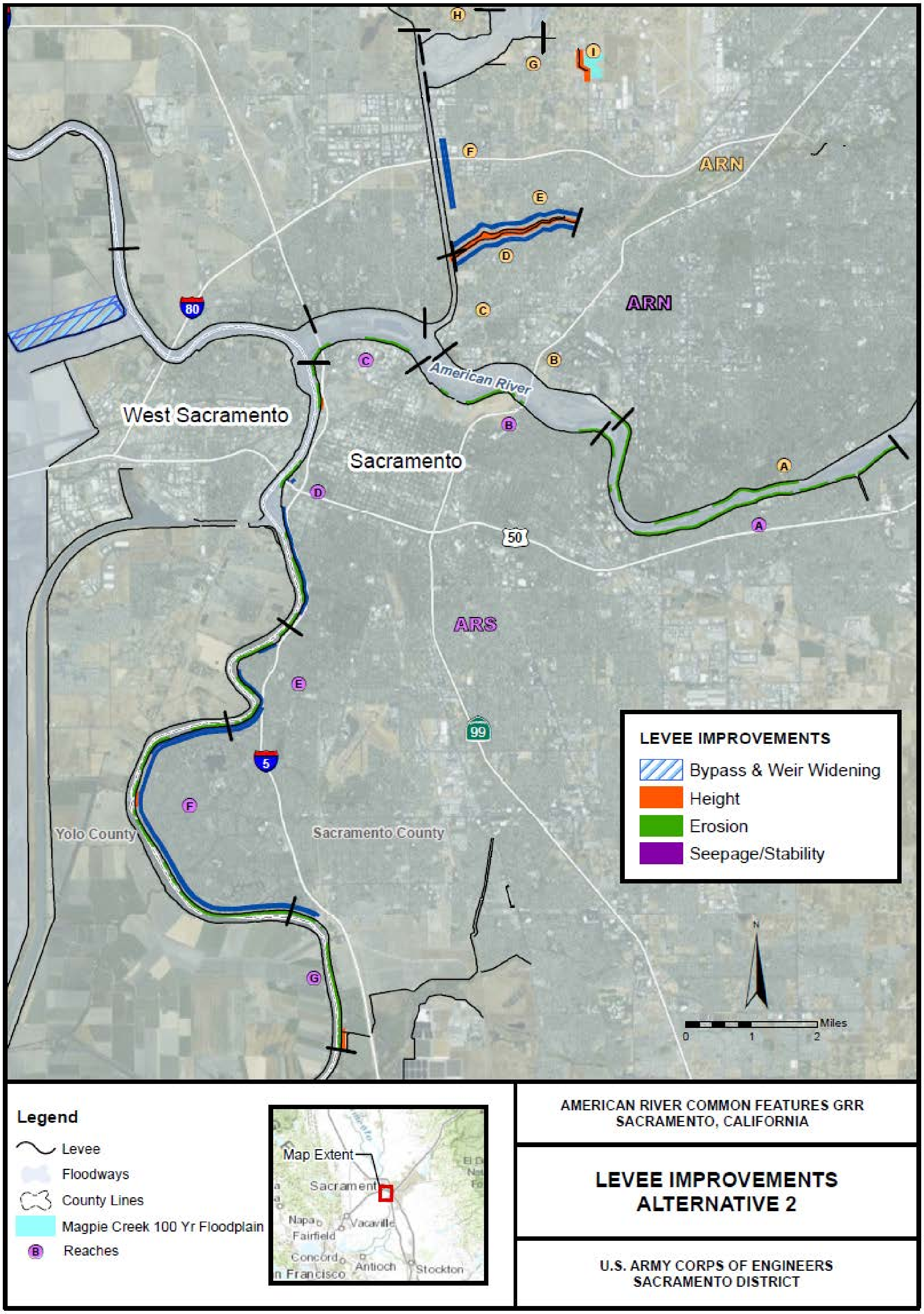


Figure 10. LPP Plan Features for the American River Common Features GRR

5.0 WEST SACRAMENTO NED PLAN

After the system-wide plans were determined to alone not significantly reduce flood risk for West Sacramento, levee improvements within the city were determined to be required for significant flood risk reduction. Alternatives for West Sacramento included improvement of the existing levees, construction of setback levees, construction of a widened Sacramento Bypass and Weir, construction of a diversion structure from the Yolo Bypass into the Deep Water Ship Channel, and construction of a Deep Water Ship Channel Closure Structure. Following are details of the NED Plan for the WS GRR, identified by basin. For West Sacramento, the NED Plan is also the TSP.

West Sacramento North Basin

- Sacramento River: Approximately 6 miles of rock riprap protection will be constructed.
- Yolo Bypass: Approximately 1 mile of seepage cutoff walls will be constructed.
- Port of Sacramento: The obsolete navigation lock from the DWSC to the Sacramento River will be removed and the Sacramento River west levee between the north and the south basins will be made continuous.
- Sacramento Bypass: Approximately 3,000 feet of rock riprap protection will be constructed.

West Sacramento South Basin

- Sacramento River: Approximately 6 miles of setback levee with seepage cutoff walls will be constructed.
- Port of Sacramento: Approximately 1,000 feet of seepage cutoff walls will be constructed. Also, the obsolete navigation lock from the DWSC to the Sacramento River will be removed and the Sacramento River west levee between the north and the south basins will be made continuous.
- Sacramento River DWSC: Approximately 1 mile of seepage cutoff walls will be constructed.
- Yolo Bypass: Approximately 5 miles of seepage cutoff walls and 19 miles of rock riprap protection will be constructed.
- South Cross Levee: Approximately 1 mile of relief wells and 0.2 miles of stability berm will be constructed.

Specific locations for the seepage, stability, and erosion improvements for both basins are shown on Figure 11 below.

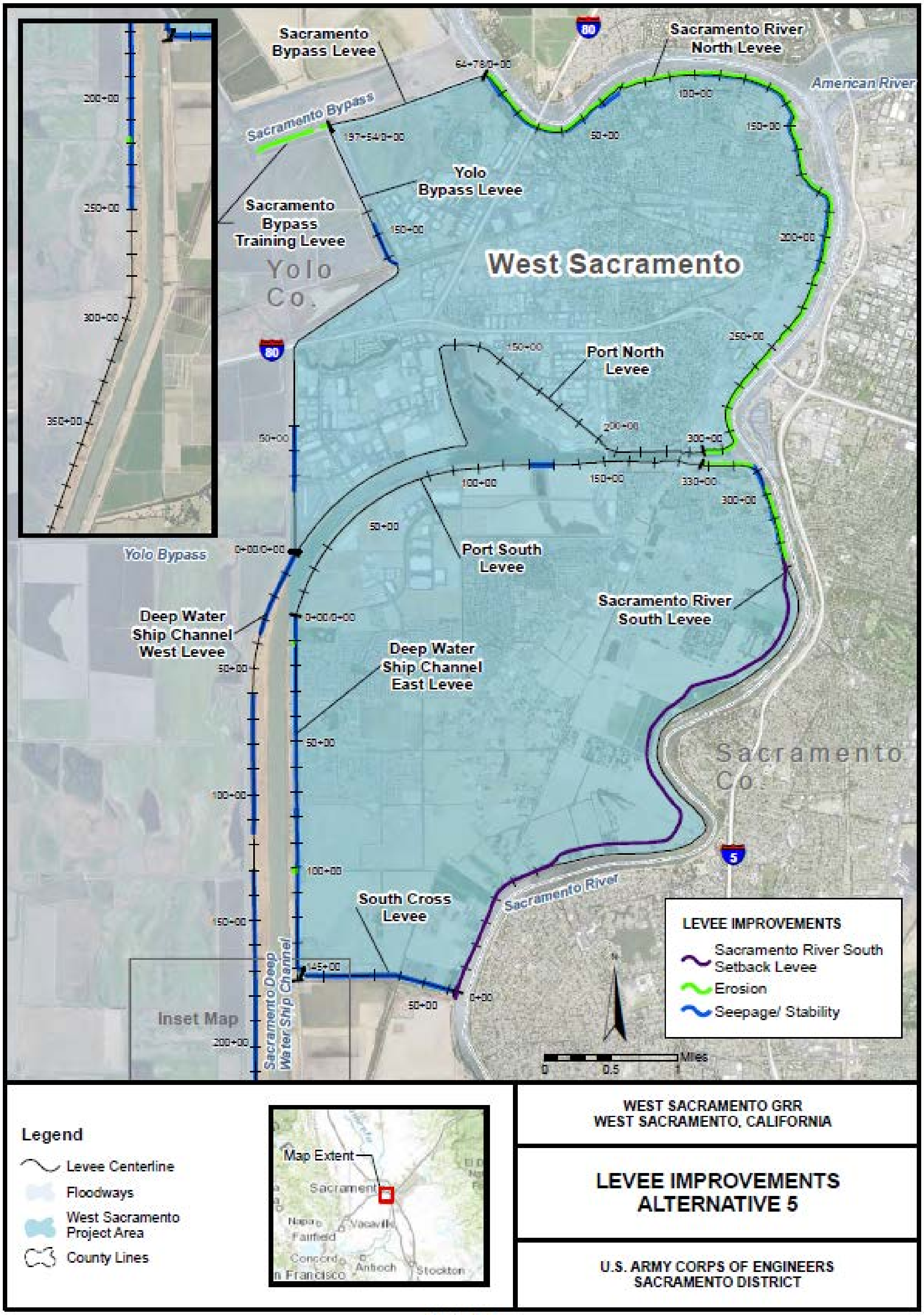


Figure 11. TSP Recommended Features for the West Sacramento GRR

6.0 EFFECTS OF RE-EVALUATING ARCF AND WS PROJECTS SEPARATELY

To determine the effects of improving levees in various basins, hydraulic analysis of the ARCF and WS study areas was performed as follows: (1) without project conditions for Sacramento and West Sacramento; (2) system-wide plans were developed and screened because they did not significantly reduce the flood risk of the two cities; (3) the ARCF TSP was considered in place but not the WS TSP; (4) the WS TSP was considered in place but not the ARCF TSP; and (5) the two TSPs were evaluated together. Details of this hydraulic analysis can be found in the Hydraulic Attachment to the Engineering Appendix for each of the two GRRs.

Step (1) in the above process confirmed the existing flood risk of the two cities as described in the background presented previously in this document. Step (2) established that there is no system-wide plan that has a significant effect on flood risk reduction in Sacramento and West Sacramento; therefore, system-wide plans were screened out. Plan formulation then proceeded to evaluate flood risk reduction measures within both cities. In carrying out steps (3), (4), and (5), it became clear that it does not matter whether the two cities are evaluated separately or together, the identification of the NED Plan would be the same

USACE engineering and economics models were used to evaluate without- and with-project conditions for each of the four hydraulic basins in the ARCF and WS study areas. Due to the practical limitations of models, the use of simplifying methods is necessary in representing the complexities of the real world. One of those methods is to evaluate each hydraulic basin separately from other basins whether those other basins are part of the same study or not. In the evaluation of each basin, it is assumed that there are no failures of levees in other basins under both without- and with-project conditions. Consequently, the proposed strengthening of an existing levee in any basin is assumed to have no effect on the probability of a levee failure in any other hydraulic basin, whether the other basin is part of the same study or not.

There is both empirical and analytical support for the assumption that there are no levee failures in other hydraulic basins. Since completion of the Sacramento River Flood Control Project in the mid 1950s, levee failures have occurred during the 1955,1983, 1986, and 1997 flood events. Detailed streamflow data necessary to determine the effect of the levee failure on stage reduction in the greater Sacramento urban area is only available for the 1997 event. An analysis was performed on the 1997 event to determine effect of the levee failures. This analysis showed that the levee failures on the Sutter Bypass and the Feather River reduced the highest stage recorded at the very upper limit of the Natomas Basin by 0.4 feet, and that reduction tapered down to zero further south within the cities of Sacramento and West Sacramento. The limited reduction in stage was due in part to the levee failures occurring near the peak of the flood. Also, the American River flows overwhelmed any minimal reduction in the Sacramento River stage that might have otherwise reached the Sacramento urban area. The levee failures that occurred during 1955, 1983, and 1986 all occurred around the peak of the flood and therefore would have resulted in similar minimal reductions in stage in the Sacramento urban area.

Analysis was performed to estimate the potential risk reduction on one side of the Sacramento River if the levee failed on the other side of the river. The specific analysis considered a levee failure into the city of Sacramento and what the stage reduction would be affecting West Sacramento. The analysis estimated that there is a 0.4 foot of stage reduction. The analysis assumed that the failure started to occur slightly before the peak of the hydrograph and developed rapidly. Actual levee failures have happened very near the peak or somewhat after the peak and have taken considerable time to develop to their full width. Therefore, the estimate of 0.4 foot is likely an upper limit.

If the worst case scenario occurred with a breach sufficiently before the peak to lead to a 0.4 foot stage reduction, the probability of a levee failure on the West Sacramento side of the river would be reduced from 23% to 18%. Because there is only a 39% chance of levee failure on the Sacramento side during a 1 in 200 (0.5%) AEP event under without-project conditions, strengthening the levee on only the Sacramento side would have an insignificant effect on expected flood damages on the West Sacramento side. For smaller, more frequent flood events, the effect of a levee failure on flood stages, and consequently on the probability of a levee failure on the opposite bank, would be even less. If the period of time before the West Sacramento levee was also strengthened was relatively short (e.g., 10 years or less), the chance of a significant flood event occurring during that period would be minimized, and the already insignificant increase in expected flood damages in West Sacramento would be even further reduced. In the reverse scenario, a single levee failure on the West Sacramento side during a 1 in 200 ACE event under without-project conditions (which has a probability of only 23%) would cause a stage reduction of about 0.4 foot, and the probability of a levee failure on the Sacramento side of the river would then be reduced from 39% to 37%. Because three low probability events are involved, strengthening the levee on only the West Sacramento side would have an insignificant effect on the expected flood damages on the Sacramento side, particularly over a relatively short period of time.

To determine the effect of re-evaluating the ARCF and WS projects separately, hydraulic analysis of the two project areas was performed in three ways: (1) without-project conditions; (2) the two TSPs were evaluated separately; and (3) the two TSPs were evaluated together. Comparison of those three scenarios indicated that combining the two projects would not result in the selection of different plans (Tech Memo, Common Features GRR and West Sacramento GRR TSP Comparison, 16 October 2014).

Table 1: Tentative Regional Construction Sequence for ARCF and West Sacramento.

REGIONAL PRIORITY	WATERWAY	REACH	YEAR OF PROJECT CONSTRUCTION										
			1	2	3	4	5	6	7	8	9	10	11-17
1	JFP/Dam Raise												
2	ARCF Sacramento River	ARS F											
3	ARCF Sacramento River	ARS E											
4	ARCF American River	ARS A											
5	WS Yolo Bypass Levee												
6	ARCF Sacramento River	ARS G											
7	ARCF Sacramento River	ARS D											
8	ARCF American River	ARS B											
9	ARCF American River	ARN A											
10	ARCF American River	ARS C											
11	ARCF American River	ARN B											
12	ARCF Sac Weir & Bypass	--											
13	WS Sacramento River North												
14	WS Port North Levee												
15	WS Sac Bypass Training Levee												
16	WS Sacramento River South												
17	WS Port South Levee												
18	ARCF Arcade Creek	ARN D											
19	ARCF NEMDC	ARN F											
20	ARCF Arcade Creek	ARN E											
21	ARCF NEMDC	ARN C											
22	ARCF Magpie Creek	ARN I											
23	WS Deep Water Ship Ch. East												
24	South Cross Levee												
25	WS Deep Water Ship Ch. West												

7.0 CONCLUSIONS

There is no system-wide flood risk management alternative that would avoid the need for levee improvements in the ARCF and WS project areas. The effect of levee improvements in one of the four hydraulic basins in the ARCF and WS project areas on any other basin is insignificant relative to plan formulation or implementation. Consequently, combining all four hydraulic basins into a single evaluation rather than two evaluations would not change the plan formulation process or identification of the NED plan for either project.